REVIEWS AND NOTES.

Economic Cycles: Their Law and Cause. By Henry Ludwell Moore. New York: The Macmillan Company, 1914. Pp. viii, 149. $2.00 net.

In his study of *Economic Cycles* Professor Moore has given added proof of the fruitfulness of the mathematical methods of curve fitting and measurement of correlation when applied to economic statistics. In his search for the law and cause of economic cycles he has subjected the available statistics of rainfall, crop yields per acre and total production, crop prices, pig-iron production, and general prices to rigorous examination, first, to determine the cycles if there be cycles, and second, to determine the degree of correlation existing between the various series of statistics beginning with rainfall and ending with general prices, the last named series being taken as the best barometer of the ebb and flow of business.

Professor Moore formulates the law of economic cycles as discovered in his investigation as follows: "The weather conditions represented by the rainfall in the central part of the United States, and probably in other continental areas, pass through cycles of approximately thirty-three and eight years in duration, causing like cycles in the yield per acre of the crops; these cycles of crops constitute the natural, material current which drags upon its surface the lagging, rhythmically changing values and prices with which the economist is more immediately concerned" (p. 149).

In judging the validity of the author's conclusion the statistical methods used are decisive. Professor Moore truly says that "the literature in which rhythmic phenomena are treated in a statistical way teems with fallacies and uncertainties. . . for the method frequently adopted of smoothing the data is so arbitrary that one is at a loss to know whether, after all, the alleged periodicity may not, in fact, be due to the process of smoothing; and, in addition, one is left in doubt as to whether an indefinite number of cycles other than the particular one deduced might not, with equal or greater probability, be obtained from the same data" (p. 7). The method selected in the present instance is that of fitting a multiple sine function to the data, called harmonic analysis. The reviewer knows of no method that better satisfies the requirements or is more rigorous than the one applied. The Pearsonian coefficient is used for measuring the correlation. This is, also, the best available method.

The study opens with an examination of the data of annual rainfall in the Ohio Valley for the period 1839-1910. There is no secular trend, but there is a cyclical variation which is closely described by a function (consisting of the first five terms of Fourier's series) showing periods of 33, 16.5, 8 and 4 years, with the 33 and 8 year periods most strongly marked. The function thus derived is found to fit, also, the rainfall data of Illinois, a section more representative of American cereal production

than Ohio, for the period 1870-1910. The coefficient of correlation for the two series of annual rainfall in Ohio and Illinois for 41 years is 0.600.

The relation of crop yields per acre to rainfall in Illinois is then investigated. The crops considered are corn, oats, hay, and potatoes, constituting 93 per cent. of the crop acreage and 96 per cent. of the crop value in 1912. Wheat is omitted "because both spring and winter wheat are grown in the state, and the statistics of their relative yield and price are not given in the published material for the long record covered in our investigation." The secular trend in the yield per acre, which is considerable only in the case of corn, is eliminated from each series. The figures thus obtained are correlated with monthly rainfall statistics of the same years. The months showing the highest coefficients of correlation for a given crop are combined and called the "critical period" for that crop. The coefficients of correlation for the rainfall of the critical period of corn and the "cycles" of corn yield per acre (*i. e.*, secular trend eliminated) is 0.589; for oats, 0.290; for hay, 0.620; for potatoes, 0.666. These high coefficients indicate that yield per acre is to a very great degree dependent upon the rainfall of the critical period. Of course, the coefficient merely tells us that the two series fluctuate together; common observation must be relied upon to designate the cause and the effect.

The data for the four crops are then combined to get indices of crop yield in general, allowance being made for the different degrees of fluctuation by using the respective standard deviations as the units of measurement. The general crop indices thus found are correlated with the mean effective rainfall of the critical periods. The resulting coefficient, $r = 0.584$, shows that the yields of representative crops and rainfall are highly correlated.

The final stage of the first part of the investigation is reached in an examination of the accuracy with which the rainfall curve having 33 and 8 year cycles describes the crop yield per acre. Professor Moore recognizes that the rigorous method is to obtain the curve describing the crop yield independently and then compare the curve found with the rainfall curve. The laboriousness of the rigorous process caused him to use a substitute method, *i. e.*, to fit the function describing the rainfall cycles to the yield data. Since the yield data satisfy a reasonable test of fit the author concludes that "the yield per acre and the rainfall of the critical season are highly correlated; the rhythmical movements of the yield and of the effective rainfall may be accurately described by a compound cycle of 33 and 8 years with their semi-harmonics; and the yield curve reproduces the general characteristics of the curve of effective rainfall" (p. 55). This conclusion appears to be justified. It is an extension of the finding of Professor J. Warren Smith, Sectional Director of the U. S. Weather Bureau, who said in the 1903 Year Book of the Department of Agriculture: "If one knows the precipitation during the month of July over the great corn-producing district he can estimate the yield of the season very closely." Professor Smith's study, to which Professor Moore does not refer, covered the eight leading corn states for the period 1888-1902; average yield per acre was

compared graphically with the average precipitation in June, July, and August. In the Monthly Weather Bulletin for February, 1914, Professor Smith continued the study, this time using the Pearsonian coefficient of correlation. He found that for the eight states during the period 1888-1912 the yield of corn per acre and the rainfall in July gave a coefficient of 0.78. In an article on "Correlation of the Weather and the Crops" (*Journ. Roy. Stat. Soc.*, Vol. 70, pp. 5 *et seq.*), Mr. R. H. Hooker made a more refined study in which he measured the correlation between crops and (a) rainfall, and (b) accumulated temperatures above 42°, based on English data.

Demand curves for each of the four representative crops were found by correlating the percentage change in production each year in the United States, as compared with the production of the preceding year, with similar percentage changes in the prices per unit. The coefficients are, for corn, -0.789; for hay, -0.715; for oats, -0.722; for potatoes, -0.856. Parabolas of the third degree, $y=a+bx+cx^2+dx^3$, are fitted to the data, giving the laws of demand for each crop. The negative correlation coefficients indicate that the demand curves slope downward toward the right, so that "the amount demanded increases with a fall in price and diminishes with a rise in price." The reviewer has found similar demand curves to those found by Professor Moore. In contrast to agricultural products, the demand curve for pig-iron slopes upward toward the right; the correlation coefficient for percentage changes in production and in price being $+0.537$. The high negative coefficient found for each of the four crops proves that Mitchell was in error when he said: "The relations between physical production and pecuniary value are decidedly irregular with agricultural products." (Business Cycles, p. 239.)

But are price changes of each of the four crops in the United States as closely correlated (inversely) with changes in yield per acre as they are with changes in total production? They are; since the coefficients for price changes and changes in yield are, for corn, -0.815; for hay, -0.656; for oats, -0.718; for potatoes, -0.873.

The fluctuations in the yield per acre of the four representative crops in the United States correspond to the fluctuations in Illinois, the coefficients figured for annual differences ranging from 0.745 to 0.855.

But is the yield per acre of the four crops taken really representative of the yield of crops in general in the United States? Statistics of the yield per acre of nine crops are available for the period 1870-1911, including all the leading cereals, hay, potatoes, and cotton. Constructing a series of weighted index numbers of the yield of the nine crops and correlating with a similar series constructed for the four supposedly representative crops the extremely high coefficient resulting, 0.960, assures us that the four crops are really representative.

Professor Moore next considers the question of the association of the fluctuations in yield per acre of the nine crops and the fluctuations in the volume and activity of trade and industry. Pig-iron production and general wholesale prices (Aldrich and Labor Bureau series) are used as business barometers. Instead of using the annual figures of crop yield, iron produc-

tion, and general prices the author uses three-year averages, e. g., the crop yield for 1895 is the average for 1894–5–6, that for 1896 is the average for 1895–6–7, etc. After eliminating the linear secular trend in each of the three series of three-year averages he obtains "cycles" of yield, iron production, and prices. The differences between the original annual figures and the three-year averages for corresponding years are called "deviations." The deviations of yield and (1) of iron production and (2) of general prices are positively correlated to a moderate degree.

The vital question now at issue is this: are the crop yield cycles (as defined in the preceding paragraph) matched by similar cycles in iron production and general prices? If so, do the cycles come in concurrent years or is there a lag in iron production and prices? Computation of the coefficients of correlation gives the following table:

Cycles of yield per acre of	Lag of (1) and (2) behind crop yield.					
	Same year.	1 yr.	2 yrs.	3 yrs.	4 yrs.	5 yrs.
9 crops correlated with cycles of						
(1) Pig-iron production	0.625	0.719	0.718	0.697	0.572	.....
(2) General prices	.....	.....	.....	0.786	0.800	0.710

The conclusions drawn by Moore from the table of coefficients are that cycles in crops precede cycles in pig-iron production by two years and cycles in general prices by four years.

The differences between the coefficients are not large enough to warrant a conclusion as to the number years of lag for maximum correlation. Computation of the coefficients of correlation between first differences of the cycles would be, however, a test of greater significance. The radical drop of pig-iron production in a year of depression, as compared with the drop in prices on crops, and the averaging of non-homogenous years, *e.g.*, two years of great activity and one year of great depression (for instance 1906, 1907, 1908), makes a conclusion based on the size of the coefficients between three year averages of doubtful value. In correlating three-year averages instead of the annual figures Professor Moore is really measuring the cumulative effects of three years of good or bad crops on business conditions as represented by iron production and prices. The coefficients for the annual figures and for first differences would have been more interesting and significant.

Statisticians and economists are deeply indebted to Professor Moore for his fine work in developing the statistical complement of pure economics.

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Some Aspects of the Tariff Question. By Frank William Taussig, Ph. D., Litt. D. Harvard University Press, Cambridge, 1915. Pp. 365.

Professor Taussig begins his exposition with a brief but sufficient statement of the theory of international trade and tariff restrictions on such